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# JOURNAL

OF THE

# AMERICAN WELDING SOCIETY

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# American Welding Society

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# AMERICAN WELDING SOCIETY

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AMERICAN WELDING SOCIETY
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## PROPOSED PRESSURE VESSEL INVESTIGATIONS

The welding industry through the American Bureau of Welding will shortly undertake a comprehensive series of investigations to secure information and data which will be of assistance in bringing about revisions and enlargements in the present A. S. M. E. Code on the Welding of Unfired Pressure Vessels and in assisting tank manufacturers in their design work.

### Program of Proposed Pressure Vessel Investigations

1. *Object.*—To secure reliable data and information now lacking which will be of assistance in revising and extending the present A. S. M. E. Code on the Welding of Unfired Pressure Vessels.

2. *Testing Work.*—The testing work will be done by the Bureau of Standards under the direction of a suitable Pressure Vessel Committee of the American Bureau of Welding of which Prof. H. L. Whittemore of the Bureau of Standards will be chairman.

3. *Funds and Materials.*—Cash funds will be raised by the American Welding Society from the interested industry. National Research Council will act as treasurer. These funds will be used for supplying the Bureau of Standards with some test assistants, apparatus, testing facilities and publication of the results. Tanks, materials and test specimens will be furnished by the interested industry.

4. *Investigational Program.*

(a) *Size of Tanks.* Unless otherwise specified the size of tanks shall be two feet in diameter, six feet in length and of ⅜ in. plate.

(b) *Method of Test.* Unless otherwise stated, tanks shall be tested to destruction by gradually increasing the hydrostatic pressure. The tanks shall be hammered near the welds at suitable intervals.

(c) The following types of tanks, at least three each, shall be furnished by interested manufacturers: (1) Lap welded seam; (2) Single vee tanks, automatically welded; (3) Single vee tanks, hand welded on one side; (4) Single vee tanks, hand welded, with slight "wash weld" on the inside; (5) Electric compression induction welds; (6) Riveted tanks; (7) Riveted welded tanks.

(d) *Special Tanks.*

A few tanks shall be made for securing information on special conditions as follows:

1. *Large Size Tanks.* These shall be of a diameter of 6 feet and a length of 12 feet, with plate material of ½ in., ¾ in. and possibly 2 in.

2. *High Pressure Tanks.* A few tanks will be tested which have been designed for working pressure of at least 500 lbs. per square inch.

(e) *Fatigue Tests on Wide Specimens.*

A number of samples are to be made up to be tested in a machine built during the war and now located at the Bureau of Standards. These samples to include riveted joints, double vee joints, single vee joints hand welded, single vee joints automatically welded, lap welded joints, single and double rivet welded seam joints, combined rivet welded and seam welded lap joints.

(f) *High Temperature Testing.* Fatigue and other physical tests will be made on welded specimens at high temperatures and also with variations in temperatures.

(g) *Tensile Tests.* Tensile tests will be made on specimens ranging in thickness from ¼ in. to 2 in. and including various types of joints and methods of welding.

The welding industry should support these investigations to the fullest extent as only in this way can be brought about changes and additions in the present restrictive rules in force. The program has been submitted to the A. S. M. E. for their review. We would also welcome suggestions for improvement from any other source. Those desiring to co-

operate in this investigation either through a contribution of tanks, test specimens, materials or funds, should get in touch with Secretary W. Spraragen, American Bureau of Welding, 29 West 39th Street, New York.

The National Research Council has consented to act as treasurer of the funds provided certain requirements are fulfilled. These requirements assure that a careful scientific study will be made which will bring about valuable results.

## COMPRESSED GAS MANUFACTURERS' MEETING

The Compressed Gas Manufacturers' Association will hold its thirteenth annual meeting on Jan. 25, 1926, at the Hotel Astor, New York City. The meeting will be followed by the annual dinner in the evening of the same day.

This association represents manufacturers of all industrial gases, such as acetylene, ammonia, carbonic gas, chlorine, hydrogen, nitrous oxide, nitrogen, oxygen, sulphur dioxide and various hydrocarbon gases. These gases are used for isolated lighting and heating plants, in the fabrication of metal by means of the welding and cutting torch, for mechanical refrigeration, for carbonation of beverages, for bleaching in the textile and paper industries, in the purification of water and sewage by chlorination, as anaesthetics, in fire extinction, and for various other purposes.

## NEW VICE-PRESIDENT

Mr. N. A. Wright was recently elected vice-president of the Pacific Coast Division to succeed Mr. C. S. Smith.

"In the absence of the president, the vice-president is the official representative of the national Society in the division so elected. The vice-president is responsible for the activities of the particular division which he represents and is also responsible for the general promotion of the Society in his division."

## RESOLUTIONS OF APPRECIATION

WHEREAS, with a commendable desire to advance the science of the welding and cutting of metals and the prestige of the American Welding Society, the Boston Section considered it advisable to emphasize the importance of the annual fall meeting of the society and the meeting of the Boston Section by holding in conjunction with such meeting an operating exhibit of welding and cutting apparatus and kindred appliances, and

WHEREAS the Boston Section, through the wise plans of the members of its committee, composed of T. A. Wry, chairman, J. W. Morrisey, R. L. Browne, J. A. Shand, H. D. Large, C. W. Babcock, H. C. Westendarp, A. Krebs, L. D. Granger, H. P. Peabody and M. B. Gleekman, made it possible to conduct a highly successful convention and exhibit at the Massachusetts Institute of Technology, Cambridge, Mass., on Oct. 21, 22, 23, 1925, thus enabling several thousand engineering students and hundreds of engineers and others to profit by what they heard and saw to a degree beyond the most sanguine expectations; therefore be it

RESOLVED, That the members of the American Welding Society, through its board of directors and executive committee, hereby extend their hearty congratulations to the members of the Boston Section and its special committee on the fine outcome of the undertaking, and also indicate to them a sincere appreciation of their excellent judgment, kindly spirit and untiring efforts, and be it further

RESOLVED, That the gratitude of the society be expressed to the ladies of the Boston Section for the unusual talent, unselfish labor and finesse represented by their cooperation, to which largely was due the success of the convention and its exhibition.

A. G. OEHLER,
*President.*

## RESOLUTIONS OF REGRET

At a Meeting of the Executive Committee of the American Welding Society, held Nov. 23, 1925, in New York City, the following Resolutions were unanimously adopted:

WHEREAS, we have learned with profound sorrow of the death of our friend and associate, Rollin D. Reed, a charter member of the American Welding Society, who died Nov. 12, 1925, in the Pennsylvania Railroad accident at Monmouth Junction, New Jersey, and

WHEREAS, in the death of Rollin D. Reed, the American Welding Socicy has lost a faithful member who cheerfully gave his ready support and wise counsel in administering the af-

fairs of the Society, and

WHEREAS, the members of the American Welding Society most deeply mourn the loss of Rollin D. Reed, whose genial personality and warm friendship will be sincerely missed but ever esteemed and treasured by all of us; therefore be it

RESOLVED: That the members of the American Welding Society extend to the family of our deceased associate, profound and heartfelt sympathy in their bereavement and that a copy of this Resolution suitably engrossed, be presented to them.

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WHEREAS, we have learned with profound sorrow of the death of our friend and associate, John C. Horstman, a member of the American Welding Society, who died Nov. 12, 1925, in the Pennsylvania Railroad accident at Monmouth Junction, New Jersey, and

WHEREAS, in the death of John C. Horstman, the American Welding Society has lost a faithful member and true worker for the advancement of the welding art,

WHEREAS, the members of the American Welding Society most deeply mourn the loss of John C. Horstman, whose friendship will be sincerely missed but ever esteemed by all of us; therefore be it

RESOLVED: That the members of the American Welding Society extend to the family of our deceased associate, profound and heartfelt sympathy in their bereavement and that a copy of this Resolution suitably engrossed, be presented to them.

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## Section Activities

### Northern New York

The November meeting of the Northern New York Section was held on the 15th in the Civil Engineering Building at Union College. Prof. H. L. Whittemore of the Bureau of Standards presented an illustrated lecture of the activities of the Bureau. Professor Whittemore explained that while the Bureau of Standards is not interested in doing actual welding, that they were interested in the testing of welds and fostering investigations of a public nature. He called attention to the fact that the Bureau of Standards has cooperated with the American Bureau of Welding in the pressure vessel investigation, and is now working on the welded rail joint investigation. There was considerable discussion on the general subject of welding structural steel.

### Pittsburgh

The regular monthly meeting of the Pittsburgh section was held on Dec. 11. Mr. G. O. Carter, consulting engineer of the Linde Air Products Company, presented a paper on "Design for Welding." A number of students from the Carnegie Technical School were present at this particular session.

### Chicago

The December meeting of the Chicago section was held on the 4th, at which time Mr. J. W. Haygood, service supervisor of the Western Division, Linde Air Products Co., presented a paper entitled, "Procedure Control for Oxy-Acetylene Welding Cast Iron Heater Sections." This paper was illustrated by lantern slides.

### Cleveland

The November meeting of the Cleveland section was held as a joint meeting with the local sections of the A.S.S.E., A.S.M.E. and the C.E.S.

The members of the four Societies met at the Hotel Winton and from there went to the plant of the Lincoln Electric Company. Arc Welding is used extensively in the Lincoln plant in the assembly of motor parts. Castings are eliminated by this process. The party then motored to the Cleveland School of Technology. The beveling and welding of steel pipe with the oxy-acetylene flame was demonstrated as well as the welding of a cast iron pipe by bronze. Mr. H. E. Winkleman of the Purox Company made the demonstrations. A table d'hôte dinner was served at 6 o'clock at the Hotel Winton.

The evening meeting was held in the ballroom of the Winton, at which time Mr. A. F. Davis of the Lincoln Electric Company presented a film showing a new building recently erected in Canton, Ohio, entirely by electric welding.

Following Mr. Davis' talk Mr. A. G. Bissell of the Westinghouse Electric & Manufacturing Co., Pittsburgh, presented a paper on the welding of fabricated steel. Mr. Bissell's paper

was accompanied by a series of slides and showed ordinary structural steel welded together under ordinary conditions and then subjected to vibration tests and crushing loads. The unusual and severe tests that his slides depicted apparently put an end to further discussion of the merits of electric welding, as the evidence of the strength of welded steel presented was so clear that no one had anything to say. Many members of the visiting engineering societies, however, were very free in expressing their surprise at the results shown.

Mr. H. E. Wetzel of the Cleveland firm Smith & Obey, heating and plumbing contractors, next gave a talk on industrial pipe welding and brought out many interesting points both as to actual cost saving in installing, elimination of expensive fittings, and one very important statement was that the heat loss on the average heavy screwed flange was equivalent to 30 to 40 feet of actual pipe exposed. Another point Mr. Wetzel stressed was the ease and economy of making up special headers requiring drips, different waste outlets, and uptakes. Mr. Wetzel also briefly outlined some of the work that will be done on one of Cleveland's newest buildings.

**Boston**

The December meeting of the Boston section was held on the 4th in the plant of the General Welding and Equipment Co. Dr. Krebs of this company presented a survey of the gas welding industry.

**Los Angeles**

A meeting of the Los Angeles Section was held on Nov. 19th. An interesting talk on automatic welding was given by Mr. Favary of the Moreland Truck Company. The next meeting of the section will be held on Dec. 17th.

**San Francisco**

A joint meeting of the San Francisco Section with the Pacific Railway Club was held on Oct. 8th. Mr. G. O. Wilson, chairman of the section described the organization of the Society, its research department, the American Bureau of Welding and the formation of the local San Francisco Section. In citing an example of the work of the Society Mr. Wilson referred to its activities in helping A. S. M. E. formulate a proper set of rules for the construction of welded unfired pressure vessels. Two papers were presented at this meeting as follows:—"Welding and Cutting in the Mechanical Shops of the Santa Fe," by H. A. Patterson, welding supervisor, Atchison, Topeka and Santa Fe. Railway, and "Welding as Applied to Track Maintenance," by C. J. Bergundthal, track welding supervisor, Southern Pacific Company. Both of these papers aroused considerable discussion.

**New York**

The December meeting of the Section was held on the 16th in the Engineering Societies Building. Mr. T. C. Fetherston of the Linde Air Products Co. presented an illustrated review of the economies, increased production and improvement in quality in welded products which can be brought about through the use of jigs and fixtures for sheet metal welding.

The January meeting will be held on the 14th. A joint session has been arranged with the local section of the A. S. M. E. The American Welding Society has been given the privilege of arranging the entire program and has provided three speakers, as follows:—"A Partial Review of Outsanding Applications of Welding," E. H. Ewertz, general manager, Moore Plant, Bethlehem Shipbuilding Corporation; "Welded Pressure Vessels," S. W. Miller, consulting engineer, Union Carbide and Carbon Research Laboratory; "Welding as a Means of Fabricating Tanks, Vessels and Pipes," William Schenstrom, welding engineer, Electric Welding Company of America.

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## EMPLOYMENT SERVICE BULLETIN

### POSITIONS VACANT

V-31. Salesmen and Estimator wanted. Required by one of the largest and best established job welding concerns in New York. Preferably a man who has experience or one who has a fair knowledge of welding, both gas and arc, and who is accustomed to doing business with large service stations and fleet owners.

An interesting proposition will be made to the right man, which assures a

good income on a salary and commission basis, to a live wire who can produce. All details will be treated in confidence.

## Services Available

A-39. Acetylene welder desires position. Have had six years' experience in welding and brazing of all metals. Have been connected with the Todd Engineering Co., The Westchester and Lighting Co., and the National Transit Pump and Machine Co. Can give references.

A-40. Welder desires position. Am an expert in oxy-acetylene welding and cutting and can also do thermit welding. Have had seven years' experience in railroad repair shops, one year as pipe line welder, one year as general cast iron welder, one year as general sawmill welder, one year as repair man and brazing of all methods. Understand preheating. Prefer a job in some northern State around Chicago. Can run a shop as welder foreman in either railroad or contract shop. Can inspect welders. Capable of being service demonstrator and salesman.

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### UNITED STATES CIVIL SERVICE EXAMINATION

**Navy Yard Service**

WELDER, ELECTRIC

Rates of Pay { $6.64 per diem / 6.24 per diem / 5.84 per diem

U. S. NAVY YARD, NORFOLK, VA.

The United States Civil Service Commission announces an open competitive examination for the position named above. From the register resulting from this examination certification will be made to fill ten vacancies at the Norfolk, Va., Navy Yard, and other vacancies as they may occur in positions requiring the qualifications tested, in the Navy Yard Service at the place specified, unless it should be found to be in the interest of the service to fill any vacancy by reinstatement, transfer, or promotion.

No educational test will be given, and applicants will not be assembled for a mental examination. The examination will consist of the subjects mentioned below, weighted as indicated:

| Subjects | Weights |
|---|---|
| 1. Physical ability | 40 |
| 2. Training and experience | 60 |
| Total | 100 |

A minimum of two years' experience in the occupation must be established in order to qualify in the second subject.

Statements as to training and experience are accepted subject to verification.

No applicant will be declared eligible for appointment who fails to attain a rating of at least 70 per cent in each of the above-named subjects. Eligibles who have been honorably discharged from the Army, Navy, or Marine Corps of the United States, and who file their honorable discharge, or a certified or photostat copy thereof, with the Labor Board, will be entitled to preference in appointment under the provision of the act of Congress, approved July 11, 1919.

Age—20 to 65 years.

Classified employees who have reached the retirement age and have served fifteen years are entitled to retirement with an annuity. The retirement age for this position is 65 years.

This examination is open to all citizens of the United States who meet the requirements. For application and examination blank, Form 1800, address the Labor Board at the address below. Applications should be properly executed and filed with the Labor Board without delay.

LABOR BOARD, NAVY-YARD SERVICE,
Norfolk, Va.

Issued November 24, 1925.

# What Occurs During the Oxyacetylene Cutting of Steel*

By S. W. Miller†

This method of severing a piece of steel into one or more parts is so familiar to us all, is done so easily, and causes so little trouble, that it is not surprising that some of the things that happen during the cutting, and some of the after effects, have not attracted much attention.

In the early days of the process it was unusual to cut steel of much more than ½ in. in thickness, neither the apparatus nor the technique having been developed for greater thicknesses, and there being no call for heavier work. It is a rather long step from such work to the cutting of skulls nearly 5 ft. thick, that requires the use of the oxygen lance in addition to the cutting blowpipe. We all know that, at the present time, there is no difficulty with the cutting blowpipe alone in handling any shape of cut in material thicker than that which we intend to consider.

Steel plate seldom contains more than 0.25 per cent carbon, but steel in the form of billets for forging purposes contains between 0.35 and 0.50 per cent carbon. As the carbon content increases, the melting point of the steel decreases; that of 0.15 per cent carbon being probably about 2700 deg. F., while that of 0.50 per cent carbon may be about 2650 deg. The melting point of iron oxide is greater than of pure irons, but the heat created by the burning keeps it fluid.

The cutting process, which is frequently called burning, is in reality just that, the burning of iron, carbon and other elements in the steel. In order that this burning may occur, it is necessary to raise the temperature of the steel to a red heat, and this is usually and conveniently done by the preheating flame of the blowpipe. When the proper temperature is reached, the cutting jet of high pressure oxygen is turned on and the burning begins.

It is evident that the preheating flame does not heat a piece 6 in. thick red hot all through. If the action is watched it will be seen that the slag, melted iron oxide, trickles down over the face of the cut, and that if this stream of slag is stopped for any reason the cutting ceases, so that what really happens is that the hot stream of oxide flowing over the surface brings a thin film of it to the temperature at which the oxygen can burn it. The preheating flame simply heats the top surface to a point which permits it to burn and make melted oxide, that in turn raises the other parts of the metal to the necessary temperature. The temperature of the melted iron oxide is evidently sufficient to bring the rest of

*Presented at October, 1925 meeting of Chicago Section, A. W. S.

†Consulting engineer, Union Carbide & Carbon Research Laboratories.

the material to the temperature at which it will readily combine with the oxygen.

In further explanation of some things that happen during cutting, it should be understood that while any pure metal, such as

Fig. 1—Section from Billet Cut Cold, Macroetched. The Dark Zone at the Bottom Is Part of the Steel, the Structure of Which Has Been Heat Altered. Full Size

iron or copper, has a definite melting point, at which the metal also solidifies when cooling down from above the melting temperature, alloys do not have a fixed melting point. For instance, 0.50 per cent carbon steel, which is an alloy of iron and carbon, while it is completely melted at 2650 deg. F., and while it begins to solidify on cooling down from above this temperature, does not become completely solid until about 2475 deg., there being a range between these two temperatures of 175 deg., within which the metal is in a partial state of fusion, the parts containing the most carbon solidifying last.

Fig. 2.

Fig. 3.

Fig. 2—Steel Billet Cut Alone. View at the Top of the Cut. Very Little Carburization Is Indicated. The Cut Edge Is at the Bottom of the Figure. 430X

Fig. 3—Same as Fig. 2, but Taken from the Middle of the Cut. There Is Much More Carbon in the Edge Than in No. 2. 430X

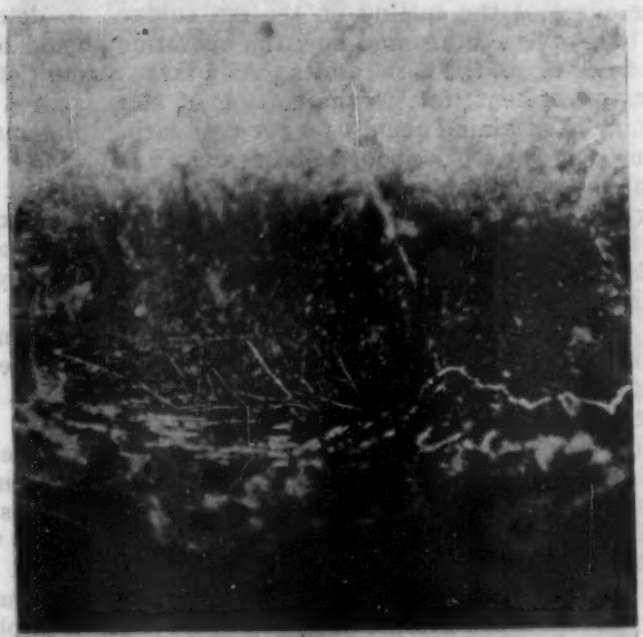

Fig. 4

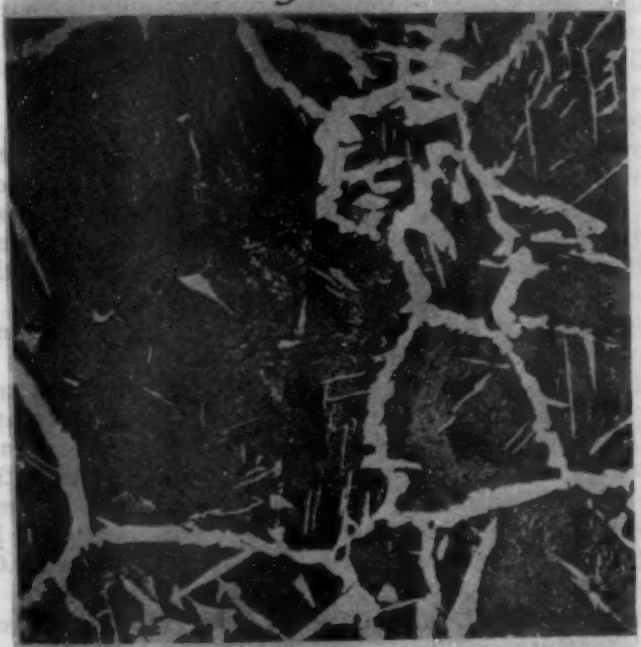

Fig. 5

Fig. 4—Same as Fig. 2, but Taken from the Bottom of the Cut. More Heavily Carburized Than Either Figures 2 or 3. 430X

Fig. 5—Typical Structure of Some Billets. 100X

With the above facts in mind, it is of interest to study more deeply the effect of the cutting on the cut surface, to determine what the best practices are and how the operation should be controlled in order to get the best results. As a large amount of work is done at the present time in the cutting of steel from 4 in. to 6 in. thick, and containing about 0.50 per cent carbon, this material has been used in the work about to be described.

The method of study was to take sections from a billet about 5 in. thick that had been cut at various temperatures, and examine them by macroetching, chemical analysis and the microscope.*

Considering first the billet cut cold, it has been shown by J. R. Dawson, in a paper read before the International Acetylene Association in October, 1922, that there is a distinct zone along the cut edge in a macroetched specimen that is darker than the body of the metal, as in Fig. 1. The dark zone, about 3/16 in. wide, is the zone that has been affected by the heat.

This dark zone is caused by the rapid cooling of the edge after cutting. The temperature of the part in the dark zone has been above the upper critical point, so that the carbon has been dissolved in the iron. On cooling rapidly sorbite is formed, which etches darker than the pearlite formed during slower cooling. This is only a change in structure, and the chemical composition has not in any way been altered, except at the extreme edge, as explained later.

The next step was to examine the cut edge and its vicinity by the microscope. For this purpose specimens were taken at the top, middle and bottom of the cut. The general appearance at these three places is shown in Figs. 2, 3 and 4.

For purposes of comparison, Figs. 5 and 6 are shown, giving typical views of the structure in the bodies of the billets examined. There is much difference in the structure of these two pieces, but it cannot be expected that billets will have the most desirable structure because there is no attempt made to heat treat them, this work having to be done after they are forged or cut into the desired shape.

In Figs. 2, 3 and 4 it is seen that the edge at the bottom contains more carbon than either of the other two or than the metal in the body of the billet. In some cases this carburization is in places much heavier, as shown in Figs. 7 and 8. The large amount of carbon is shown by the white needles of cementite, shown to be such by etching with sodium picrate, which darkens cementite, as in Fig. 9. Fig. 8 indicates a percentage of carbon of from 1 to 1½ per cent in a zone about 0.004 in. to 0.005 in. thick. Fig. 7 shows that there is some increase in carbon to a depth of 0.01 in., beyond which the carbon content has not been changed.

As long ago as 1921, Roth and Ness of the Linde Air Products Company laboratory at Buffalo reported this carburization of the

*The photomicrographs are not in all cases from the same billet, but have been selected to show typical appearances.

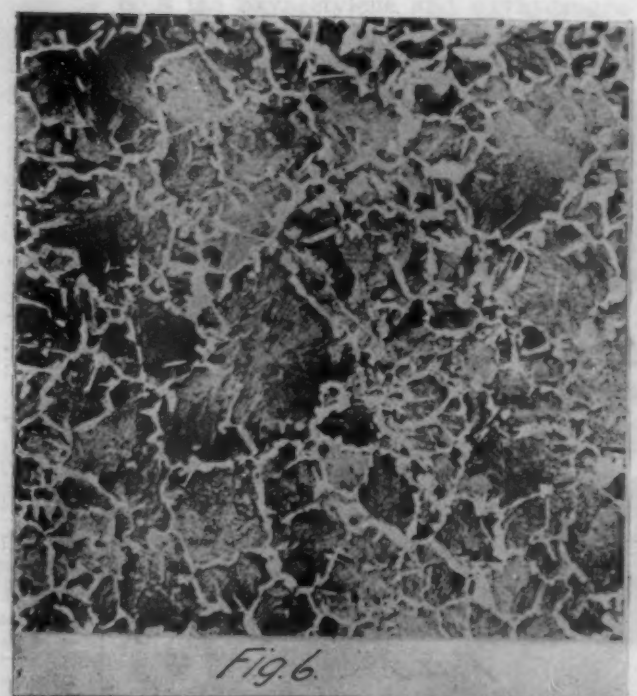

Fig. 6

Fig. 6. Structure Typical of Other Billets. 100X

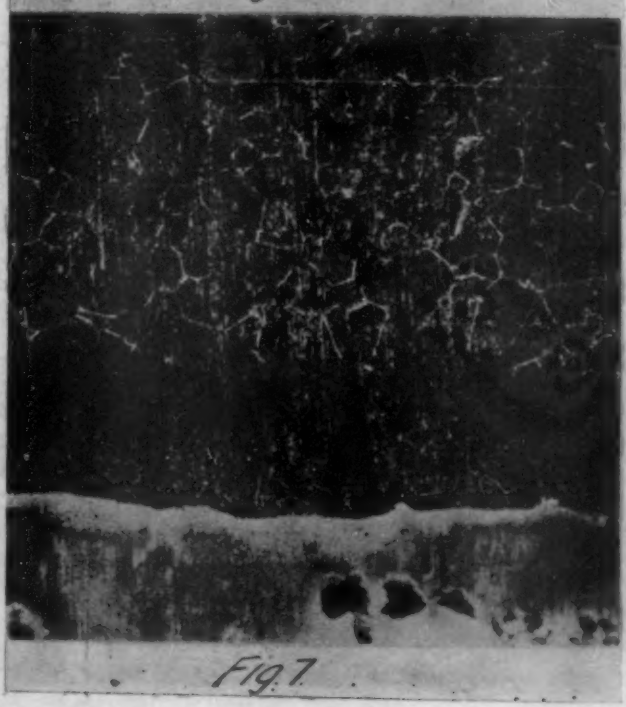

Fig. 7

Fig. 7—Section of Billet Cut Cold. High Carbon Edge, Showing Microcrack in the High Carbon Zone but Not Extending Beyond It. These Cracks Are Frequent, but Seldom Over 0.01 In. Deep. The Cut Edge Has Been Copper Plated, as Shown Below the High Carbon Edge. 100X

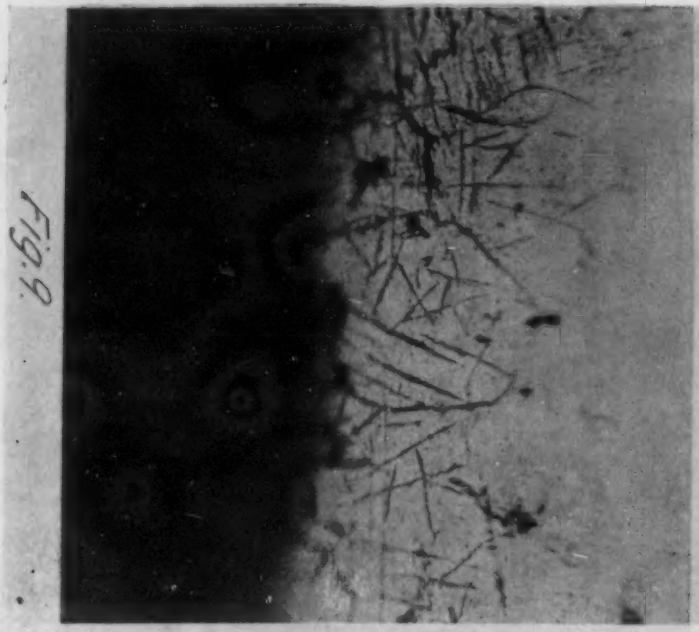

Fig. 8—Showing Maximum Depth of Very High Carbon Edge About 0.005 In. In This Zone, Indicated by the White Plates of Iron Carbide, the Carbon Content Will Average About 1.5%. Back of This Zone, as in Fig. 7, the Carbon Content Is Higher Than in the Base Metal, but Less Than in the Zone of This Photograph. 430X

Fig. 9—Carburized Edge Etched with Boiling Sodium Picrate, Which Darkens Iron Carbide. The Dark Plates Are the Same as the Light Ones in Fig. 8. 430X

cut edge by both the oxyacetylene and oxyhydrogen flames, and their chemical analyses, given in Table I, shows an increase of carbon in the cut edge. These results have been confirmed by the present work, during which four layers, as thin as could be conveniently removed by machining, were analyzed, the results being also given in Table I. The layers were about 0.002 in. thick, and in view of the roughness of the cut surface, the irregularity of the very high carbon spots, and of the small increase in carbon at the top of the cut, it is clear that each layer was only an average metal containing quite different amounts of carbon in its different parts, and so it could not be expected that any such amount of carbon would be found as the microscope shows as a maximum. There is, however, a distinct increase in carbon in the outer layers.

TABLE I

| Original Carbon Content, Per Cent | Haynes and Ness .24 | Haynes and Ness 1.35 | This Report *.50C. |
|---|---|---|---|
| C. in 1st layer | Average 40C. | Average 1.46C. | .66C. |
| C. in 2d layer | | | .63C. |
| C. in 3d layer | | | .52C. |
| C. in 4th layer | | | .49C. |

*This steel contained 0.65 per cent Mn., 0.045 per cent Sulphur, 0.024 per cent Phosphorus, 0.16 per cent Silicon.

The source of this additional carbon is of interest, and there seem to be only three possibilities:

1. The $CO_2$ in the atmosphere
2. The acetylene
3. The steel itself.

It is believed that the first one can be dismissed at once because of the very small quantity of $CO_2$ in the air, which would be insufficient to account for the increase found. It is well known that steel can be carburized by the action of the excess acetylene flame, but it is improbable that there is any excess acetylene in the preheating flame of the cutting blowpipe, because we have found it invariably true that the oxygen consumption in the preheating jet is greater than that of the acetylene, and because the operator does not use an excess acetylene flame. It should be further pointed out that the same effect is had with the oxyhydrogen flame, in which there is no carbon. It, therefore, seems impossible that the carbon can come from the acetylene of the preheating flame.

The remaining possibility, that the carbon comes from the steel that is cut away, seems to account for the facts in the case. During the cutting operation, the iron and carbon in the steel combine with the oxygen readily. The carbon is oxidized to either CO or $CO_2$. There are also other possible reactions, but whatever these may be, there is evidently formed a large amount of CO, which is one of the most active carburizing agents known, so that it is easy to see that at the high temperatures of the cut edge, it may be easily carburized by this gas.

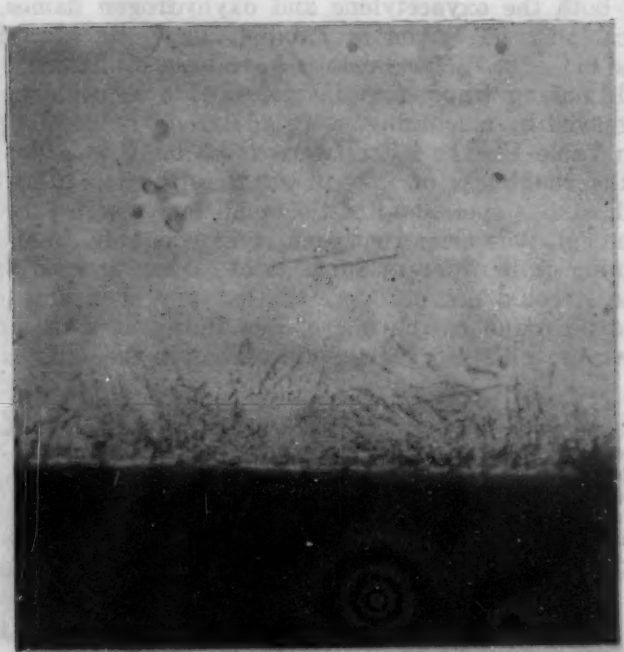

Fig 10.

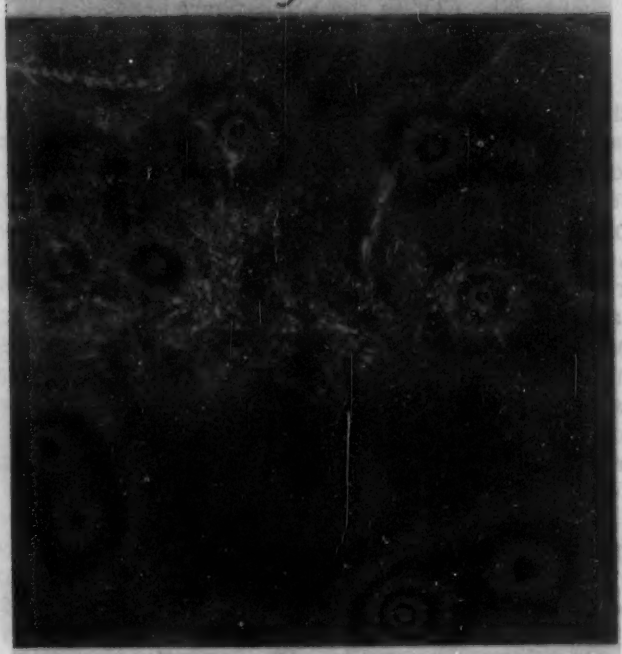

Fig 11.

Fig. 10—From the Bottom of the Armco Iron Billet Cut Alone. Some of the White Plates at the Edge May Be Due to Nitrogen, but Even if They Are All Iron Carbide, the Carburization Is Very Slight. 430X

Fig. 11—From the Bottom of the Steel Billet Cut on Top of the Armco Iron One. Quite Heavy Carburization. 430X

Fig. 12.



Fig. 13.

Fig. 12—From the Bottom of the Armco Iron Billet Cut Beneath the Steel Billet. Very Lightly Carburized Edge. 430X

Fig. 13—Same as Fig. 4, but Another Crack at Higher Power. Many of These Cracks Are Close and Parallel to an Iron Carbide Plate Which May Influence Their Direction and Location. Iron Carbide Is Weak and Brittle and So It Makes the Steel Less Resistant to Stresses. 430X

The kerf is about ¼ in. wide in metal of the thickness worked with. The maximum depth to which the cut surface is carburized is about 0.025 in., and in this zone the average increase of carbon is about 35 per cent. It is, therefore, clear that there is more than enough carbon released from the kerf metal to account for the increase in the amount of carbon in the cut edge.

In order to test this theory, two 4 in. square billets, one of Armco iron, which contains practically no carbon, and the other of 0.50 per cent carbon steel, were treated as follows: Each billet was first cut separately and photomicrographs taken of the cut edges. With the Armco iron there was a trifling increase in carbon, some of the appearance of the microphotograph indicating carbon increase being probably due to nitrogen. With the .50 per cent carbon billet, the cut edge was as usual heavily carburized. Then each billet was machined off on one side, so that they would fit closely together, the high carbon billet was placed on top of the Armco iron one, and a cut was made through both together. The results are shown in Figs. 10, 4, 11 and 12. As in all other cases, the amount of carburization was greater at the bottom of each billet than it was at the top, so only the photographs from these locations are given. As the Armco iron was heavily carburized, it is evident that the extra carbon came from the steel billet.

It is well known that in cutting a steel plate or billet, the edges of the cut back of the blowpipe become curved. This is of course due to the expansion of the cut edge by the heat. There are reasons that will be given later for believing that there is a thin zone along the cut faces that has been brought almost, if not entirely, to the fusion point. The heating of the metal causes the cut face to expand and this expansion is resisted by the colder metal back of it. At the high temperature of the cut edge, the metal at this point tends to be compressed or upset by this resistance. As it cools off, any upset or shortened metal tries to resume its original length but cannot without going beyond the yield point of the material. Therefore, the cut edge is more or less stressed. With low carbon material, especially if it be thin, so that the cut edge is but little carburized, these stresses are harmless, but with higher carbon steels, where the carburization can be of considerable extent, microscopic cracks are formed at times, that, if allowed to remain, may result in fracture of the piece later in service, especially if it has to undergo alternating stress or shock.

The harmlessness of these stresses in low carbon steel is proved by tests made on ordinary structural steel, such as I beams and channels, which show that there is no more danger in bending an edge cut with the blowpipe than in bending one cut cold with a saw (that is, both will bend 180° without cracking), and even less danger than when sheared or cut with a friction saw.

One of these microscopic cracks is shown in Figure 7 and another in Figure 13. None of them was found to extend inward beyond the carburized zone. Their formation is doubtless helped by the comparative brittleness of the face, high carbon steel being more brittle than low carbon material.

As these microscopic cracks may be a source of danger in service under certain conditions, it is well to remove them by machining the piece. As the heat altered zone does not extend into material 6 in. thick more than ¼ in., machining will remove not only the cracks, but also all stresses that may be in the edge of the piece.

Other methods for removing the carburized zone have been tried, such as grinding, annealing and sand-blasting. Grinding is slow and expensive, though it will do the work, but care must be used to avoid deep scratches, as they reduce the strength of the metal. Annealing is desirable in any case if the best physical properties in the froging are desired and it does decarburize the surface, but in order to remove the carburized zone effectively, the atmosphere of the annealing furnace must be oxidizing or the piece must be left in the furnace a long time. The usual method of annealing, done for the purpose of improving the physical properties, requires that the piece be left in the furnace but little longer than necessary to bring the whole mass to the proper temperature, after which it is removed and allowed to cool in the air. The proper length of time for this treatment may not be sufficient to decarburize the face, unless an oxidizing furnace atmosphere is used, and then there is danger of injuring the steel, so that the uncertainty of this method prevents it from being satisfactory; also it does not remove any minute cracks unless carried to extremes. Sand-blasting is effective if used for a long enough time, but it does not remove the irregularities due to the cutting, that, having more or less of a notch shape, tend to weaken the piece when it is subjected to service stresses. It therefore appears that the best way to accomplish the desired object is to machine off the entire heat altered zone.

The effect of preheating was examined next, although no endeavor was made to get exact temperatures, as it was felt that in a large piece, the preheating temperature could not be kept uniform during the cutting. The temperatures were roughly—bright red, dull red, and not quite red. Photomacrographs of these are shown in Figures 14, 15 and 16, and photomicrographs in Figures 17, 18 and 19.

It will be noticed that in the piece cut red hot, the edge has been decarburized to a slight depth, instead of being carburized. In the one cut at a dull red heat, there is somewhat less decarburization but it is still noticeable. In the piece cut below a red heat, there seems to be practically no change in the carbon content.

The probable reason for this decarburization is that the red

hot piece allows any surplus oxygen to act on it and combine with the carbon. While the cutting operation is quite efficient, that is, the theoretical amount of oxygen necessary to turn the kerf metal into oxide is not very largely exceeded in practice, yet, the efficiency cannot be 100 per cent, so some excess oxygen is always

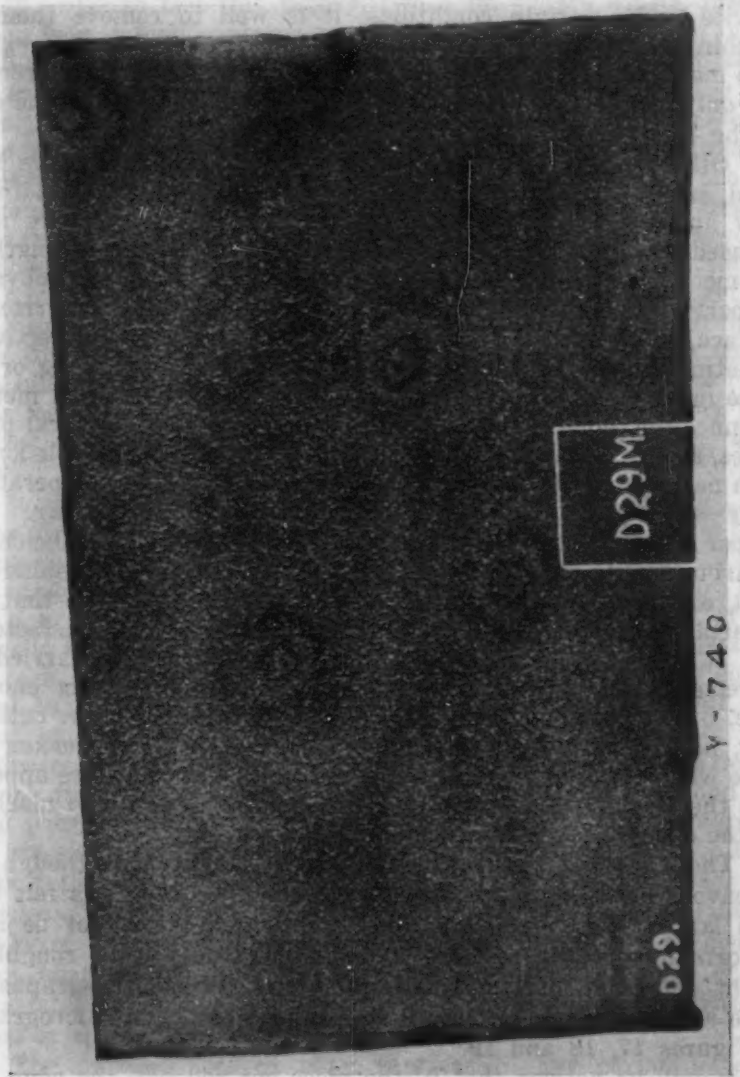


Fig. 14—Macroetched Section from Billet Cut at Bright Heat. No Darkened Edge. Full Size

present. This oxygen can combine readily with the carbon in the carburized edge when it is red hot as in a preheated piece, while in a cold piece the face of the cut back of the edge is cooled so rapidly that the oxygen cannot act. As the preheating is increased, so is the decarburization.

One peculiar difficulty was found in pieces that had been preheated. It is probably best shown in Figure 18, and consists of a large number of cavities in the face of the cut. They are also noticeable in Figure 19. They are probably due to the absorption of gases by the highly heated metal, which gives them out on

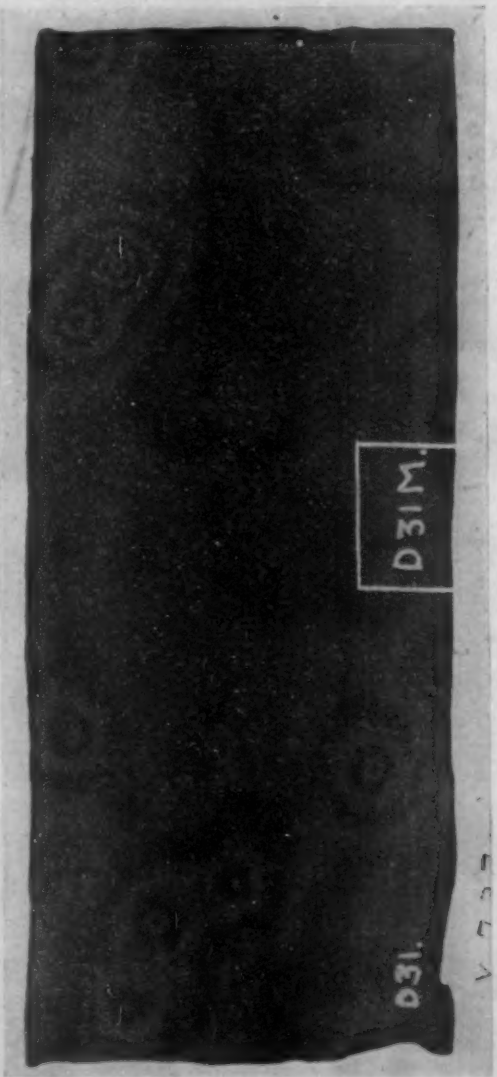


Fig. 15—Same as Fig. 14, But Cut at a Dull Red Heat. No Darkened Edge. Full Size

cooling, leaving the cavities, so that while a proper degree of preheating will prevent carburization, it introduces another difficulty which is just as objectionable, because these holes tend to act as notches and weaken the steel, although no microscopic cracks were discovered in the specimens heated before cutting. Again, there-

fore, we are compelled to advocate machining of the piece in order to remove such defects.

Another very interesting feature from a metallographic standpoint will be noticed in Figure 18. It is also visible in Figure 19. An enlarged view of the former is shown in Figure 20. These

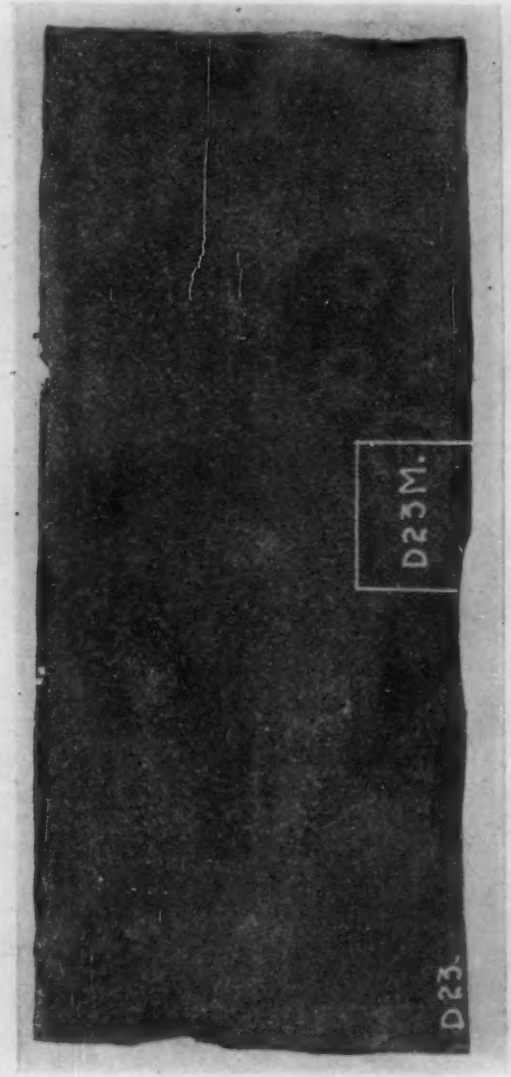


Fig. 16—Same as Fig. 14, But Cut Just Below a Visible Red. Still No Darkened Edge. Full Size

figures show the formation of idiomorphic* crystals of iron in the zone just next to the edge of the cut.

Under ordinary condition of cooling of steel or iron, it is not

*Idiomorphic crystals are those of regular shape. Different materials crystallize in different forms, that for iron being a cube.

Fig. 17.

Fig. 17—From Section in Fig. 14 Showing Decarburized Edge. 100X



Fig. 18.

Fig. 18—From Section in Fig. 15 Showing Slightly Decarburized Edge. Note the Holes Back of the Edge, and the Idiomorphic Crystals of Ferrite. 100X

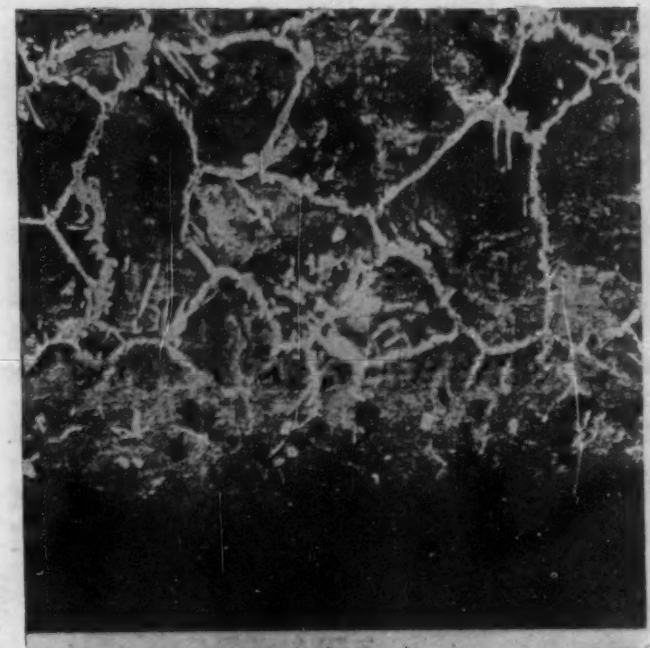

Fig. 19

Fig. 20

Fig. 19—From Section in Fig. 16. Cut Edge Shows Practically No Change in Carbon Content. 100X

Fig. 20—Same as Fig. 18, but 430X Shows Holes and Ferrite Crystals More Clearly

possible for the grains to take on their regular external crystalline form, but under extreme conditions of plasticity, that is, when the metal is partly fused, this regular crystallization may occur. It will be noticed in the photographs that there are small defects in the center of each crystal of ferrite. These are probably small dots of oxide which remove the carbon from the steel, combining with it as CO which passes off as gas. The pure iron that is left is a nucleus on which it is comparatively easy for other atoms of iron to build up. It therefore is evident that the zone in which this occurs has been very highly heated, as was referred to earlier in the paper, and the blowholes or cavities are also strong evidence of the high temperature.

There are many other interesting phenomena that occur during the cutting of steel of heavy sections, but enough has been said to enable us to say what should be done to ensure successful cutting in the material considered, and we may conclude that

1. Heavy billets should be preheated to a dull red before cutting, to avoid stresses set up in the cut edge.
2. That the heat affected zone which may contain minute cracks, should be removed, preferably by machining, if the piece is to be subjected to heavy service stresses, especially if these stresses are alternating or induced by shock.
3. If annealing or other heat treatment is required, it should be done after the cutting and before machining.

Finally, it should be understood that none of the difficulties spoken of have been found in steel of less than 35 per cent C, so these precautions are not necessary when cutting boiler plate or other low carbon material.

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# Shop and Employment Tests for Qualified Welders*

By G. O. CARTER†

Successful welding is built on the basis that the welder is qualified. This is irrespective of the process, be it Oxy-Acetylene, Electric or Hammer.

The fact that an operator has proved his ability to make a good weld is by no means complete assurance that he will never make a poor weld. But a proper test for qualification will make sure that the welder is capable of depositing metal of the strength desired and then if subsequent tests show that workmanship was poor there can be a definite placing of the responsibility on the welder for failure to do his best. Experience has indicated that welders maintain a high average standard in their daily work.

Qualification tests should be made with and on almost identically the same materials that the welder will work with and on.

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*Presented at November Meeting, New York Section, A. W. S.
†Consulting Engineer, Linde Air Products Co.

This is of prime importance as welding conditions vary where there are considerable differences in the thickness of the base metal, the composition of the metal and the composition of welding rod. It is of such importance that where a man who is known to be a good welder on certain materials is considered for welding in important work with some other material, he should make a qualification test to assure good workmanship. For instance, a man who is a good welder on 1½-in. steel plate may be, and probably is, a good welder on heavy cast iron, but it is obvious that the work is of such a different nature that the good steel welder *might not* be good on cast iron.

The conditions in welding light material of, say from 20 gage up to 10 gage, vary so from welding on ½-in. plate that check test should certainly be made before a welder accustomed to either weight of steel starts on the other.

The question now arises as to what is a satisfactory qualification test. In my opinion a welder should be called upon to make a short test weld of from 3 to 6 in. or more and this test piece should be cut into strips 1½ to 2 in. wide and the strips tested by bending in a vise or over an anvil. This simple test is a very effective one for judging the ability of a welder. This test is, however, one that is a matter for the opinion of the supervisor and can only be evaluated with difficulty. It shows the soundness of the deposited metal and the amount of penetration.

In most cases of welding on average materials the management would not need to carry a test any further, but if a welder is to work on important welding where the joint is being called upon to withstand severe loads an additional test is decidedly advisable. This may involve a real expense for testing, but when the test has been made and results reported everyone from the engineer who supervises the welding to the management of the welding shop and the welder will be glad to have the information.

In many cases applicants for welding work are good welders with other apparatus than that to be used for the welding considered. Therefore, if a man being checked asks to use equipment with which he claims to be familiar or with a different welding head and pressure than is specified for the job, it will be well to let the applicant prove his ability (if he can) by furnishing him with the desired apparatus. If a man is a good welder with one type of apparatus, it would justify the spending of a few hours or a couple of days to let him learn how to handle the equipment that the management will provide. The final test should, however, be made with that equipment, that material and under the conditions that will be met in the actual work.

For an exact test it is desirable to have the test pieces made up of material of almost the same thickness and quality as the finished work. It is also advisable to have the test pieces of such size that they can be compared with other tests results both in welding and in standard materials.

On this account in plate metal work test pieces should be 9 in. wide by 12 in. long and if they are to be beveled, the beveling should be along a 12-in. edge. When the weld has been made joining two 12-in. edges, the plate will then be 18 in. long by 12 in. wide. If the plate is of steel the test pieces can then be roughed out with a cutting torch so as to obtain strips for machining or grinding out five standard A.S.T.M. flat test pieces. If material is other than iron or steel, the plate will have to be cut up into strips by some machine tool.

After the plate is cut into strips each test piece is then machined out at its central part so that the standard 8-in. test can be marked off over a section which will be 1½ in. wide. There will be some excess metal at the grip as is the regular practice. In cutting the strips from which the test pieces are to be made, it is good practice to cut ½ in. off each end of the weld so that the testing of the workmanship will not be complicated by the initiation or the finishing of the welding operation.

These test pieces will then be pulled in a tensile test machine and reports should show the elastic limit or yield point; the ultimate strength; elongation, both in 2 and 8 in., and reduction of area. The report should also indicate the nature of fracture and if failure has occurred in the weld what percentage of the area was not welded on account of lack of penetration or blow holes.

In some cases the welds are ground flush with the plate, but it is now common practice to leave the welded zone unground on the flat surfaces as that is the way the weld will be in the finished article. The thickness of the material should be noted and an average cross section of the weld zone should also be noted. If failure occurs in the weld the strength of deposited metal should be calculated both from the cross section area of the zone of fracture and on the basis of the cross section of the plate. If, however, failure occurs outside of the weld zone, the strength of a test piece should be calculated only on the cross section of the base metal.

With different grades of deposited metal, different standards should be looked for. In oxy-acetylene welding with Norway iron, which is so very low in carbon as to have a maximum strength of about 52,000 to 55,000 lb. per square inch, a welder should develop a strength of weld through the weld zone of 40,000 lb. per square inch, for single Vee weld or 45,000 lb. per square inch for double Vee. With Norway iron, the failure will nearly always occur in the weld, because almost any steel plate is stronger thon 45,000 lb. per square inch.

In oxy-acetylene welding with nickel steel filler of good quality or with high test welding rod failure should occur in base metal of average steel as frequently as in the weld zone. A qualified operator should develop at least 50,000 lb. per square inch with either of these materials or, if he is an excellent, his test should develop approximately the full strength of the plate—60,000 to 65,000 lb. per square inch.

What the limitations should be for quailification test with other forms of welding should be left to those thoroughly familiar with the welding process being used.

From these standard A.S.T.M. tests we get figures which can be depended upon to satisfy us as to the ability of any given welder and by building up a series of qualification tests we will be building up a history for the welding industry that will materially assist in carrying it ahead in the esteem of engineers. When a welder is making his qualification test, attention should be paid to several things that will have an important bearing on the question of workmanship. Whoever supervises the test should set a maximum time within which the test should be completed because a welder should be expected to do a certain minimum day's work. Attention should also be paid to the size of the welding head which is used for the test work. Manufacturers of blowpipes, will, undoubtedly, specify a certain welding head for any given thickness of metal and it is advisable to have a test conducted when the apparatus is used under the conditions considered most satisfactory by the maker of the equipment.

Experienced welders know that by using a very carefully adjusted flame, with gas pressures as low as can be carried and still permit operation of the torch without backfiring, a very high quality weld can be made. Such men also know that by taking their time they can make a better weld than they generally average. The qualification test should not be intended to show what is the very best that a man can do, so much as what he can be counted on to do under working conditions.

Thus, by having the welding heads as called for by the equipment makers and using the pressures specified by them and insisting upon a commercial speed of welding a test piece will be made which gives real information.

We can rest assured, moreover, that if a man makes a very satisfactory test piece, even if he has worked a little slower or with a *slightly different flame than is his general practice*, we will be very much better off than if he did not make a satisfactory qualification test of any kind.

From consideration of the above it is easy to see that we may divide the work into at least two categories. One is work which must be of the very best quality; here it is important to have the full qualification test and it will be satisfying to everyone to have such tests supervised by competent inspection laboratories. For the other class of work where life is not endangered by failure of a joint, it is advantageous to have a good check on welders' ability, but the simpler test which is made by cutting the test piece into strips and bending them in a vise is quite sufficient.

The history of the welding process where real qualification tests have been utilized over a period of years is so satisfactory that we can truthfully say welding is equal in quality to any other type of joint and, of course, in tightness is far superior.

# Welding and Cutting in the Mechanical Shops on the Santa Fe*

By HAROLD A. PATTERSON†

The history of fusion welding and cutting on the Santa Fe begins about the year 1908, when experiments started with the oxy-acetylene flame, and it has grown through these years until today wherever metals are worked, even to our B & B and similar gangs, a welding and cutting outfit is part of their equipment. It has grown so rapidly that in one shop the ratio of welders increased 14 to 1 over a four-year period. Our present welding organization consists of a welding supervisor, a system official with offices in Topeka, Kansas. A corps of instructors, furnished by a service company, constantly moves over our lines, and in shops large enough to warrant such, a foreman welder is employed. Our test department, in conjunction with our welding supervisor, works out the technical side of our welding problems.

Of course, the early experiments resulted in many failures. I can vividly recall years ago when the oxy-acetylene flame was in its infancy, a certain man endeavored to weld the tubes to the tube sheet of an old superheater condensor. He worked with a welding flame about six inches long, knowing little at that time of any such thing as a neutral flame, and as he would weld one tube, the tube just previously welded would pull loose with a bang. He worked many hours over this job, and as fellow workers were making a sport of his efforts he was about to give up in despair when a wonderful thought crossed his mind. Goaded by the jeers of his fellow workers, that night, when all were in bed he slipped back to the shop, opened the condensor and filled it up with a very liberal dose of sal ammoniac and water. It was several days before the condensor was tested, and by that time the sal ammoniac had performed its work nobly; it had rusted the inside of the condensor so thoroughly that it was declared O. K. and this man was pointed out in the shop as the man who had so successfully welded the tubes in that condensor. Of course, a job of this nature could not hold up long, and welding today is paying the price by the prejudice of men gaining their knowledge of welding failures where in many cases the welding had been really performed by sal ammoniac or some kindred agent, and the welding process itself misapplied.

At this time little was known of the proper application of the different processes; little was known of the proper preparation of work to be welded; the welding rods were poor and little attention was paid to the effects of the weld heat on certain metals.

*Presented at San Francisco Section meeting, October, 1925.
†Welding supervisor, Atchison, Topeka & Santa Fe Railway Company.

However, as time went on and failures occurred and successes were recorded, it led to a new idea and the Santa Fe management saw the necessity of appointing a welding supervisor, a system official, a man conversant with the needs, the problems, the possibilities, and limitations of the welding science; so this man was appointed and he compiled a welding folio, a manual based on successful operations and sound engineering judgment. A copy of this folio is placed in the hands of all supervisors under whose immediate supervision welding operations are performed. The forward page of this folio reads:

"To all Mechanical Department Heads: This folio describes methods of making repairs by the Oxy-Acetylene and electric arc processes. Any recommendations for revisions should be submitted by the Mechanical or Shop Superintendent. When changes or revisions are made, sheets will be sent out to all holders of the folio and discarded sheets must be removed and sent to Supervisor of Welding Equipment for cancellation. Officers will see that the instructions contained herein are complied with."

This sheet is signed by Mr. John Purcell, our head mechanical official.

So you can see this gives us an opportunity to suggest revisions, making it possible for any one having an idea of merit to have it written into the folio. As developments are made in the welding field new pages are distributed covering these developments and thus we are kept up to date. This folio gives us a blue print and printed instructions covering every standard operation on a locomotive or car; for example page 10 of our folio described the method of welding half sides and door sheets in locomotive fireboxes.

*Preparing Half Sides and Door Sheet for Autogenous Welding*

When removing the old portions of fire box sheets, the horizontal lines of weld should be centrally located between rows of staybolts. Lines should be drawn to a straight edge and plainly center marked so the cutting operator can work to a straight line which minimizes the work of fitting new sheets. The operator should hold his torch so that the cutting nozzle will point downward approximately 45 degrees, to bevel the sheet and to eliminate excess chipping.

When new plates are being fitted they should be bolted in place and strut bolts used to hold them in position; seams should have not more than 3-16 inch opening at the bottom of Vee of seam and beveled per sketch 1-A. Should the new plate being applied to firebox have two horizontal seams, that is, a welded seam just above the mudring on account of the lower portion of the old firebox at mudring being in a good condition, the plate should have a 1-16 inch opening at the top horizontal seam and 3-16 inch opening at the bottom seam and tack welded every 12

inches, each tack weld being approximately 4 inches long, then proceed to weld all intermediate spaces alternating from the center space to the next space, using what is known as the back step movement and proceeding in the direction most convenient to prevent drawing the sheet out of line. After the bottom seam has been welded the sheet will have drawn approximately 1-8 inch and it may be necessary to chip a small portion of the plate applied to secure the proper opening for welding the top seam, conducting the welding in the same manner as explained for the lower seam using the back step movement. The vertical seams should be tack welded in a similar manner as explained for the horizontal seam using the back step movement until all intermediate spaces are entirely completed releasing strut bolts before the weld becomes cold.

*Method of Welding Broken Frame*

When frame is broken, same must be expanded to 1-16 in. when electrical process is being used. Start at the bottom part of scarf. Apply one layer of metal, and same must be brushed thoroughly with wire brush before proceeding with the next layer of metal. After center section of frame is welded, two welders may be placed on same job, one on each side, working from the bottom up. Always be sure to reinforce welds 20 per cent when same can be done. Be sure to remove wedges and jacks when operation is complete, in order that it may contract equally. When frame is broken, as per figure 2, same must be expanded at least 1-16 in., when electrical process is being used. Apply 1-4 in. plate as shown at letter A. Fill center section of frame, being sure to brush each layer of metal as it is being applied. Start welding at bottom, proceed through the center of frame, to top, then return to bottom; deposit another layer of metal and repeat process until weld is complete, as shown in sketch (finished weld). Manufacturer's "A" wire, grade No. 6, to be used in connection with this process, machine set at 140 to 145 amperes.

When frames are to be welded by gas welding, No. I rolled steel must be used. Always be sure expansion necessary is allowed, then pre-heat frame until orange color appears. Then proceed with two welding blowpipes, one on each side of frame, welding center section first, and continuing from center out until complete. Be sure and reinforce weld 20 per cent when same can be done. Always remove jacks and wedges from parts expanded immediately after operation is completed, so as to allow contraction.

*Rules for Welding Flues to the Back Flue Sheet of Locomotives*

Flues must not be welded to the back sheet until the locomotive has made at least one trial trip or has been fired up at least ten hours.

It is preferable to make several trips before welding, providing this can be done without loss of time or increased expense.

*Method of Welding Flues in Sheets*

Flues are to be set in the regular way, as per page 14 of the Locomotive Folio. Flues must be sand blasted or roughed with a roughing tool, to remove any scale from the flue beads or sheets. Copper must not be allowed to project from under the flue beads. Be sure that flue sheet is free from grease or dirt, fill boiler with warm water, about 100 to 125 degrees, to above the top of the flues. Begin welding at top row of flues, weld across the row, then take the next row down, and so on until all are finished. Start the weld at the bottom of each flue, follow up one side to the top, then the same process on the opposite side. Set machine at 125 to 150 amperes; use 5-32 in. welding wire on superheater flues and 1-8 in. wire on small flues.

NOTE: 5-32 in. wire may be used on small flues when 1-8 in. wire is not available. Welders should try to deposit the welding metal so that it conforms to size and shape of Standard flue beads for size of flue being welded. Avoid applying more weld than necessary.

When flues which are welded in the back sheet begin to leak, the old welds of the leaky flues should be entirely removed, the flues thoroughly worked with expander and beading tool and then rewelded. It is not good practice to patch a weld on a flue; all the old weld should be removed.

When welding flues that have not been previously welded, but have been in service for some time, flues should be thoroughly expanded and beaded and sheet sand blasted or roughed with a roughing tool, shown on plate No. 27, the boiler filled with water and welded the same as for new flues.

The first year after flues on all locomotives on the Santa Fe were welded, the engine failures due to flue failures were reduced 75 per cent. Richmond, California; San Bernardino, California; Topeka, Kansas; Albuquerque, New Mexico; Cleburne, Texas, or into which ever shop you go, you will find these operations all performed in the same manner and that is just as I have read them.

So you can see a skilled operator working under formulas like these has little opportunity for failures. Our Welding Supervisor, boiler inspectors, mechanical inspectors and others are constantly checking our work and, of course, criticizing any departure from the folio.

An interesting part of railroad welding today is the reclamation of freight car castings. These castings are reclaimed on the Santa Fe under the following rules as outlined on page 3 of our folio. It reads:

"In the year of 1924 there were 5744 truck frames, truck

bolsters, body bolsters, and side frames welded and 119 failures reported. Of these 119 failures 18 were welded on our own lines and the balance on other railroads, or not stenciled."

Under the present state of development, the Santa Fe recognizes certain limitations in fusion welding and these are described in our folio.

*Rules Covering Welding and Handling of Car Castings*

(1) Car castings with fractures in tension members should be forwarded to central points for welding and annealing as follows:

Shopton for Eastern District, Eastern Lines.

Topeka for Western District, Eastern Lines, including Wellington and Hutchinson.

Albuquerque for Western Lines, Northern and Southern Districts, including Gallup and Winslow.

San Bernardino for Coast Lines.

Cleburne for Gulf Lines.

(2) All worn castings such as side frames, truck frames, or bolsters can be welded at local points.

(3) All defective compression members can be repaired by autogenous welding at local points.

(4) Castings which appear to be porous at a point of fracture should be given careful consideration and should not be welded if metal appears to be 50 per cent porous. (Fractures in any tension members of over 40 per cent of the total area through the section at point of fracture should not be welded.)

(5) Coupler heads which become defective such as fractures in back wall, knuckle lock hole, and inside face cracks can be welded. (a) Elongated and fractured knuckle pin holes in coupler heads must not be welded.

(6) Worn coupler shanks may be built up solid to the original thickness.

(7) Coupler knuckles may be built up only at heel when worn and must conform to standard gage.

(8) Bent coupler bodies may be straightened in blacksmith shop.

(9) All coupler bodies or knuckles which show to be porous at pin holes must not be welded.

(10) All worn drawbar yokes may be built up by the autogenous welding process to the original thickness and annealed.

(11) Exception to the preceding rules.

*Rules Covering Welding and Handling of Car Castings When Necessary to Avoid Delay to Cars Under Load*

Castings which are fractured in tension members less than 40 per cent of the total area through the section at point of frac-

ture may be welded at local points, provided the castings are not porous and that the castings are removed from car, welded and annealed.

NOTE: When furnace is not available for annealing, castings must be annealed in a wood fire, using scrap lumber for annealing fire, heating the casting to 1400 to 1500 degrees Fahrenheit and allowing same to cool in the atmosphere.

(12) Car castings shipped in from outside points must be used at point where welded; however, any surplus of such castings may be returned after being welded and annealed to outside points from where they were received.

All points should use repaired castings when they are available.

All rewelded castings must be restenciled and old identification marks removed.

Each individual weld must be stenciled per instructions.

1208 Forms must be furnished for all welded castings placed under cars and showing all information as per instructions printed thereon.

Many will ask you which process is the best, which you prefer, and why. I am going to ask you, Mr. Master Mechanic, which do you prefer? A lathe or a boring mill, a milling machine or a drill press, a planer or a shaper; and you, Mr. Boiler Foreman, which do you prefer? A rivet or a patch bolt, a stud or a plug? You prefer which ever suits that particular job you desire to accomplish. It is results you are after. If you had a heavy job to perform which would require a deposit of 200 pounds of weld metal, then you would prefer the thermit. If you desired to plug a small but deep hole in a large steel casting, then you would prefer the electric. If you desired to braze a collar or a copper pipe your choice must be the gas. It is a parallel case. They are all tools best adapted to different operations.

Another big subject is the qualification of a welder. One of the biggest electrical men of California recently said to me, "Welding is a science as great as that of electricity." Mr. Service Supervisor of Welding Equipment on the Santa Fe, in a paper read before the Chicago Section of the American Welding Society, said, "As early as 1908, even at that time while fusion welding was but little understood, it was realized that this type of tool for use in repairing and building up might be a wonderful help, but could easily be made a two edged sword which if not properly controlled would do so much harm that it would offset the advantage which would accrue from its use." Granting these two statements to be true, put a man on a job with a tool like Mr. Service speaks of, working at a business that is as much of a science as electricity, then this man must be a careful, intelligent man under a capable supervisor. On the Santa Fe every welder is required to submit to the test department a monthly test plate.

This plate is broken and analyzed and the welder's weak spots are pointed out to him.

Are you still willing, Mr. Master Mechanic, when you have a welding job open, to bulletin the job and give it to any mechanic in the shop whose seniority entitles them to a preferred job, or have you some definite procedure that unmistakably informs you that the applicant is capable? You spend four years to make a machinist, a boilermaker, or a sheetmetal worker. Do you honestly think you are giving your welding needs the same consideration?

I contend that in railroad welding today there is a vast variance, and to explain my contention I am going to quote a few extracts from a government inspector's report on two boiler explosions. The first boiler had a welded fire box crown sheet. The inspector's report says: "The rupture extended down to between the 10th and 11th longitudinal rows of radial stays, from the center of the crown sheet through the solid plate just back of the riveted seam of the flue sheet until it reached the left side sheet seam which connects the crown and side sheets. This seam was autogenously welded, the tear then followed this seam, the entire length of the side sheet to the door sheet then followed through the seam which connects the door and crown sheet shearing the rivets in this seam to the right side sheet crown sheet seam, from the right back corner of the right side sheet seam which is autogenously welded. It tore through this seam along the right side to a point 36 inches from the back flue sheet. In other words, the entire crown sheet was blown down, the rupture following every available welded seam." Judging from my own welding experience I know something was faulty about that seam.

On the other explosion which happened on the Santa Fe, the inspector says: "The transverse welded seam of the crown sheet patch extending through the overheated section of the crown sheet held, the welded seam between the door sheet and crown sheet held, but the door sheet ripped open a distance of 40 inches." Now, Mr. Master Mechanic, if you have a case of low water on an engine turned out of your shop, which kind of a report do you want to read about your welded seams? And you must have welded seams if you are keeping abreast of the times. Have your pressure welding performed under a capable supervisor and don't be misled by every man that calls himself a welder simply because he can light a torch or draw an arc, and in conclusion let me leave this to you:

Worry kills men; fusion welding properly executed kills worry.

# Welding As Applied to Track Maintenance*

By C. J. BERGUNDTHAL†

Welding has become a very valuable factor in the maintenance of railroad track material, and the Southern Pacific Company was one of the pioneers in the development of this economical practice. As early as 1913 the Southern Pacific built up two crossings by the oxy-acetylene process, one located at 6th and Townsend Streets, the other at 5th and Bryant Streets, San Francisco. This work proved so satisfactory that a few crossings and frogs were built up as a further experiment in freight yards and other locations of slow speed track. Up to this time the tonnage was such that the wear on track material was quite unimportant compared to what occurred later under much heavier traffic.

During the year 1915 about 14 million gross tons were handled over the Sierras. During the year 1917 about 22 million gross tons were handled over the same track and practically the same rail. This showed an increase of 57 per cent in just two years. The Motive Power Department was compelled to increase the efficiency and power of the locomotives for such enormous increase of traffic. Prior to 1915 the company operated their trains mostly with locomotives such as the Pacific, Consolidated and Ten-wheel Types, drivers weighing from 141,000 lb. to 194,000 lb., except in mountain districts, where Mallets-Consolidations and a few Mallet Moguls were used. But when the rapid increase in traffic in 1916 and 1917 demanded more power, the company purchased about fifty 2-10-2 type locomotives, drivers weighing 273,000 lb. Because of this increased weight of power and traffic, a great many rails developed battered ends. During this same period there was an extreme shortage in labor and high cost of material. These prevailing conditions compelled the maintenance department to devote their greatest attention to labor-saving devices and methods of reclaiming material.

As I have previously stated, cropping the rail was the method used in repairing battered joints. However, this involved far too much labor and interference to traffic, and some other method had to be developed to take care of the situation.

It was then decided to build up the battered ends by the oxy-acetylene process. As a result, some 5000 battered joints were welded on the Salt Lake and Los Angeles Divisions in 1918.

This work proved so satisfactory that the company increased its welding forces to a present organization of about eighty men, including welders and helpers. Up to the present time the Southern Pacific Company has built up approximately 250,000 joints. The cost has been reduced about 55 per cent from 1918 to the

*Presented at San Francisco Section meeting, October, 1925.

†Track welding supervisor, Southern Pacific Company.

present time. Last year 75,000 joints were repaired, covering about 1400 miles of track. The amount of money involved would have renewed only about 13 miles of track or would have reclaimed only 85 miles by the old method of cropping, redrilling and relaying the rail. In addition to this, all delay in traffic was eliminated.

Not only does welding reclaim the rail, but it saves ties, spikes, angle bars and bolts from wearing. It also saves labor in maintaining a smooth riding track. Train movements passing over the battered joints cause an excess amount of vibration which works the ballast from under the ties, thus developing a low joint. Battered joints cannot be tamped up.

We have made every effort to obtain the best welders. At first it was difficult to get them to go to work in remote sections of the line. But that difficulty has been overcome, and all our welders are now thoroughly trained and efficient in their line of work. The quality of work has improved as rapidly as the cost has decreased.

Each division has a gang of welders consisting of from 2 to 14 men. Where more than one welder is operating, a lead welder is employed to take charge of the outfit. These gangs are housed in outfit cars which are moved from one location to another, keeping the men close to their work at all times. Each welder is equipped with a complete welding outfit.

Before the welder starts to build up joints, the section forces close up excess expansion and apply rail anti-creepers to the track, tamp up the ties and renew the angle bars if necessary. The welder then builds up the joint in the following manner: The parent metal or rail contains a certain necessary percentage of carbon. When the welder applies his torch and heats the metal to a molten condition, this molten metal coming in contact with the atmospheric oxygen decreases the carbon content because of the oxidation that takes place. To overcome this, a welding rod is used, made up of some alloy like nickel to take the place of the carbon lost. We use nickel welding rods and find them ideal for this work. After the welder has deposited sufficient metal on the rail to bring it to its required level, the molten metal is allowed to drop in temperature until it is cherry red in appearance. It is then hammered to produce a closer grained metal, and to give the rail its proper shape. Finally it is smoothed up with a "flatter."

We do not build up frogs, switch points or mates in main line track, because they are subject to special track stresses where the welded metal would not be adequate. Fast train movements cause a great amount of side motion when passing over switches and frogs, making it necessary for the thin metal at the points to possess a great tensile strength. This cannot ordinarily be obtained by welding because the structure of the metal does not allow a high tensile strength. As I have stated, rails and other materials, such as frogs and switches, are made up of high car-

bon steel, and its chemical composition is such that when the metal is in a molten condition it is hard to handle; in fact, it attracts atmospheric oxygen to such an extent that the carbon consituents evaporate very rapidly. The built-up metal does not have the same physical or chemical composition as the parent metal. In the thin portions of switch and frog points there would be danger of the weld breaking at the point of fusion.

You may ask why these conditions do not apply to battered rail ends.

The reason for this is that the ends of the rails are largely subjected to impact and compressive stresses; they do not require the tensile strength of the switch and frog points. The portion built up on the rail end with nickel steel has good wearing quality and compressive strength. Furthermore, the rail end has a larger mass and gives a better base to build up on than the thin point of a switch or frog.

However where the movements of trains are very slow, such as in freight yards and terminals, we build up a great many frogs and switch points. In these locations the company also uses frogs and switches removed from main line track and reclaimed by welding.

In addition to gas welding, considerable work has been done with the Electric-Arc process. Three years ago the company purchased a gas engine generator outfit, which has worked constantly in Los Angeles, building up battered joints and manganese castings, such as frogs, crossings and switches. An additional machine was purchased recently, which is operating on the East Bay Electric Division, building up battered joints. About two years ago 100 joints were built up by this process, on high speed main line track of the Sacramento Division as an experiment. The results have led the company to venture further into this method of welding.

A special procedure is required in building up worn manganese castings. This is done as follows: Before the operator deposits any metal, he grinds the portion of the casting to be built up, removing all defective metal and obtaining a smooth and solid foundation. He then uses an electrode containing from 12 to 14 per cent manganese. This electrode is coated and is applied as the positive electrode, making the casting negative. After the metal of each electrode is deposited, it is quenched with cold water. Manganese steel has peculiar properties, and if allowed to cool slowly will become brittle and hard and in a short time will disintegrate and flake off. After the metal has been cooled, it is hammered, stretching the metal as well as loosening the coating that flowed off the electrode on the deposited metal. It is then cleaned with a wire brush and is ready for the application of another electrode. By following this method, the part built up will have great ductility and wearing qualities.

We have expanded our welding practice to cover other branches of work in addition to the repair of track facilities. For example, the steel plate roofs of large oil storage tanks have been welded to make them gas-tight. This has been accomplished with much less labor and expense than would have been required had they been riveted.

In conclusion—the process is being applied to an ever-increasing field of usefulness; in conditions to which it is particularly adaptable; where it gives a result which could not be secured by other methods; and where it constitutes a most valuable, economical and efficient facility.

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## Discussion Papers, "Welding and Cutting in Mechanical Shops of the Santa Fe" and "Welding as Applied to Track Maintenance."

President McKelligon: Wish to thank you, Mr. Burgundthal, for your very fine paper. The subject is now open for discussion.

Mr. F. L. Perkins: Welding has done more to reduce the scrap pile than any other invention that we ever had. It is a method that if properly handled will reduce the cost of operation very materially, but we must have good welding metals, operators and supervision. Much depends upon the supervision. When arc welding was first introduced, attention was drawn to the perfecting of a material that would give the best results—they had found that one material would not do for all welding—the engineers spent some time experimenting and today we have welding materials for the different metals. If you have a steel of 18 point carbon and 45 point manganese that you want to weld, you must use a welding rod of approximately 22 point carbon, 75 point manganese and some copper. In passing through the high heat of the arc, part of the carbon is burned out, part of the manganese is burned out and all of the copper, leaving a metal of about 19 point carbon and about 50 point manganese and no copper, which would be about the same as the parent metal so it is seen that to produce a finished job and leave the metal strong and ductile you must have a good welding metal. If you do not have that you will either burn the parent metal or deposit something on top that will slack off. A welder of today must have some knowledge of the different points of fusion and he can depend on the manufacturers of welding metals to supply him with the kind he needs for his particular purposes. Our mistake to a great extent today and heretofore is to consider that a welder is a welder on his say so, give him a torch and start him out. We are trying to eliminate that state of affairs but we will never do it if a man is permitted to pick up a torch or an electrode who does not know what he is doing, and it is hard for the supervisor to watch every move because the supervisor

nowadays has a great many things to look after, but there should be supervision to know what metals are being used and that gas is not wasted. Many a man wastes more gas than he can save by the job he is doing if he does not know the size of tip to use. If everyone concerned with welding will interest themselves enough to make a little study of the heat required and learn something of metallurgy, we will get results. We cannot expect the ordinary welder to be a metallurgist or an electrical engineer, but if he understands sufficiently to do what he is told we will be able to still further cut down the scrap piles.

Mr. Wilson: I think we are most fortunate in having with us a man like Mr. Perkins who can look back in his own experience and view the progress in the history of welding.

I have also been interested to hear these railroad welders all agree that the factor of greatest importance is this matter of training welders. It is just that point particularly that we are trying to put over with the A. S. M. E. They have formulated their code on the basis that there is going to be some poor welders, and that the code must be so conservatively framed so that the poor welder cannot do any damage. We believe that to be a wrong theory. Mr. Patterson has told of their tests. Mr. Burgundthal has told of the training of their welders and I believe we can get competent men to do our welding, hence it is necessary to formulate a code to protect against incompetent welders. That can be taken care of by proper supervision.

Mr. J. P. Flood: I would like to ask Mr. Burgundthal if in the process of building up battered rail ends by the oxy-acetylene method, it is any different from building up any other similar job?

Mr. Burgundthal: No, I cannot say that it is.

Mr. H. C. Venter: Mr. Patterson talked about welders—they should not be machinists, blacksmiths or boilermakers—I say they might be either. Question comes up—which is best? Oxy-acetylene or electric—I believe they are both good but the nature of the job must determine which method is best suited.

The thought has entered my mind that the railroads do not take full advantage of the opportunity to reduce claims for damage on certain shipments by reason of repairs that can be made by welding and perhaps do not realize how much is saved in that manner. I know on our road we are saving a good deal in freight damage claims that way, and I must say that both the acetylene and the electric processes have helped to reduce the claims to a great extent. It was only a year ago that the power shortage existed in California —there was a large condenser shipped over our line from Tennessee —it was valuable in that it cost in the neighborhood of $12,000.00, and it was almost a matter of life and death to the power company who were waiting for it—they must have it by the 1st of July—it was needed to distribute the power to the farmers and industries to pump the water so badly needed by reason of the dry spell. This

casting had been broken in transit. We were sent to look it over and say what could be done with it. The shippers would only accept one sort of weld—the acetylene—telegrams passed back and forth between the company and this firm in Tennessee and they insisted upon the acetylene weld. Finally they were told we would take the responsibility if they would let us use the arc weld and they consented. The job was successfully accomplished and they accepted it. That is only one of the many valuable ways in which the railroad companies are helped to reduce damage claims through various forms of welding.

Mr. Rennick: We do not work with a folio except in boiler work. The other work is prepared in a careful way and we are careful about the welders we put on a job. We move the men along to more important jobs as the men themselves progress. All our welders have to weld a test plate. The best men are kept on pressure work.

Mr. J. P. Flood: I would like to ask Mr. Burgundthal if the method of using oxy-acetylene in building up battered joints is common practice or is it patented?

Mr. Burgundthal: Common practice. It is not patented that I am aware of.

Mr. H. C. Venter: I would like to ask Mr. Patterson if they have any way of checking the welding work on their boilers? Can they go back in event of trouble and ascertain when and by whom the welding work was done? We have a log book in which we keep all necessary data so that in case of need we can determine just when and who did the work.

Mr. Patterson: All our welding is recorded on our boiler charts. We know just when and where and by whom the work was done.

Mr. Wilson: We do a great deal of welding on our oil lines where any failure would be extremely important. All welders who do that kind of work for us, and the best men get the most important jobs, are given a number which is never duplicated. Every few feet they stamp that number, so if there is any failure we know just where to place the blame. I am glad to say that we have never had occasion to make use of these numbers. We have had at times over 300 welders, and we have never had a failure.

Mr. Perkins: I might add something to that. While we do keep a record, we have not had a failure on a locomotive boiler. Our welders are well trained, and while we keep the chart record, it has never been necessary to refer to it for the purpose of ascertaining who was responsible for a failure.

Mr. Binkley: Mr. President and Gentlemen: The street railways are using welding quite extensively both in street work and in the shops. They have built up joints for a number of years. They are also welding the joints which they can do successfully where the tracks are buried. In Chicago, one of the earliest cities to inaugurate the practice, practically all the joints are welded.

President McKelligon: Mr. Perkins referred to the scrap bins being depleted due to activity in welding. The Stores Department

have a great deal to with the scrap; it is at the scrap bins that the defects or the wearing qualities of materials develop. Formerly, it was not possible to repair certain materials by any means at hand and it was necessarily sold as scrap. Since welding by the various methods has been generally adopted at all of our scrap concentration points, such material is again returned to service.

E. J. Becker, General Stores Inspector, Southern Pacific Co.: Have listened with great interest to the remarks of the previous speakers pertaining to the technical side of welding. However, believe it would be of interest to members and visitors of our club to briefly outline a few of the activities which are being accomplished through oxyacetylene welding by the Store Department at its reclamation plants.

First, due to the geographic location of our railroad, district stores are located at Sacramento, West Oakland, Los Angeles, Brooklyn and El Paso, to which points scrap accumulations of all kinds are shipped and at which points reclamation plants are maintained. Scrap at these various points is sorted by expert workmen and in sorting they seldom, if ever, miss picking out a piece of material which can be reclaimed either by welding or through other methods which may be made serviceable for future use.

To better illustrate what is being accomplished by oxy-acetylene welding, will state that during the year 1924 at reclamation plant, Sacramento District Store, we reclaimed through method of acetylene welding:

| | | |
|---|---|---|
| 1452 Couplers | Scrap Value | $ 1,353.11 |
| | Total Cost to Reclaim (Material and Labor) | 8,910.20 |
| | New Value | 19,992.24 |
| | Saving | 11,082.04 |
| 3459 Coupler Knuckles | Scrap Value | 975.06 |
| | Total Cost to Reclaim | 5,000.76 |
| | New Value | 15,986.88 |
| | Saving | 10,986.12 |
| 356 Switch Points | Scrap Value | 584.11 |
| | Total cost to reclaim | 2,558.20 |
| | New Value | 8,439.20 |
| | Saving | 5,881.00 |

or a total saving on these three items during year 1924 of $27,949.16, and during the past five and a half years we have reclaimed by oxy-acetylene welding at reclamation plant, Sacramento District Store a total of

2286 Switch Points, 9506 Coupler Heads, 17,204 Knuckles, which resulted in a net saving to our company of over $250,000.

In addition I might state that notwithstanding the vast number of items which are welded daily we have not received a complaint on any of the work turned out, and believe that this is particularly due to the fact that each welder not only takes an active interest in the work which he is handling, but also is required to

mark each coupler, switch point, etc., with his initials and the date the work is performed.

President McKelligon: Thank you, Mr. Becker. I might say at this time for the general information of all, that the question might be raised that such material is not as good as new material, but from our observation and records in connection with failures of such materials we feel that the value of new material is the only correct way to figure the savings developed.

William Brown, Brown Bros.: I feel a little out of place in talking before a railroad club because I am not a railroad man, but after all is said and done, welding is welding, no matter where you find it and the general rules will apply.

Our own particular field is job welding and marine welding. Our welding operations on boilers on vessels are controlled by the Federal Inspection Service. Federal inspectors pass on a job before we do it, tell us how far we may go, watch the work and inspect it after it is completed. They are very particular—they have to be on account of the particular hazard involved.

The rules for welding marine boilers are no different from any other boiler. The main thing is to get a competent welder on the job and we find that the men who go home to their families, remain with them and show up on the job in the morning, are steady men, with steady habits and do good work. Men with previous mechanical habits and training have an advantage in a general welding shop because we have so many different kinds of jobs, obstacles to be surmounted, considerable judgment to be used, and a man must be physically fit.

I noticed in a magazine that the Santa Fe had issued a folio on welding and wrote to Mr. Serviss requesting a copy, which was kindly supplied me. I have never read anything that is so complete an authority on welding and it should bring about a uniformity in railroad welding that I do not believe could be gotten in any other way.

The welding in a job shop is alittle different from the welding in a production shop. In a job shop you get anything and everything to weld. Some of the jobs you have to turn down. A man brought a broken crankshaft to me but I told him to get a new crankshaft.

Proper supervision is essential. A welding torch is a dangerous tool. We had a rather clever man working for us on a vessel, the rivets had been marked out for him but he went along the whole line and cut through the hull just above the water line. We were in a jam and it looked like a dry dock job, but we overcame the difficulty by electric welding. I would like to ask Mr. Burgundthal what character of metal he uses in electric welding?

Mr. Burgundthal: A high carbon rod.

Mr. Brown: I would like to ask Mr. Patterson if they roll the tubes after welding?

Mr. Patterson: No, we do not.

Mr. Wilson: We are building a reservoir out near Antioch and

running a 16-in. line through the bank to take the oil in and out. On the strength of that line will depend upwards of $3,000,000 worth of oil. Two of our best welders worked on that job; the welds were hammered and annealed. We had this line, 16-in. pipe, about 150 ft. long, in place but the contractor decided to make a change in the layout, hitched a tractor to it and pulled it out of place—one end was on the floor of the reservoir and the other on the bank with no support in between—but the line did not break. That speaks well for the strength and durability of the welding.

Secretary Woller: I think to make the meeting complete, mention should be made of the service that the welding manaufacturers have been to the railroads. Their representatives get around to the different shops and they tell about what is going on on the various railroads. We do a great deal of welding and much of it is based on information that is handed us without cost by the representatives of the several organizations and I think they should be given credit for it.

Mr. Wilson: I will try to respond on behalf of the manufacturers. The Welding Society has tried to foster that spirit. There was a time when the man handling gas welding tried to show that electric welding was no good, but that day has gone and they realize there is plenty of room for both methods.

President McKelligon: I quite agree with Mr. Wilson and Mr. Wollner as to the service men, not only in the welding but in all other activities they have been of great service.

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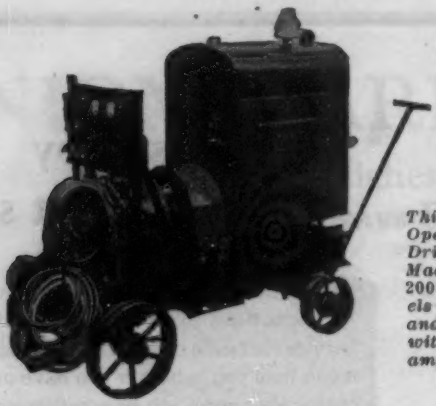

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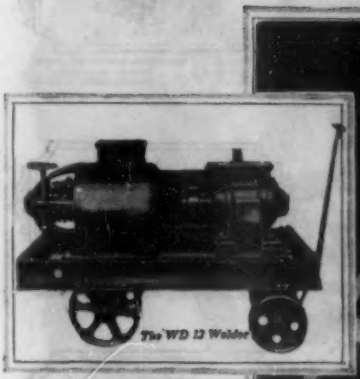

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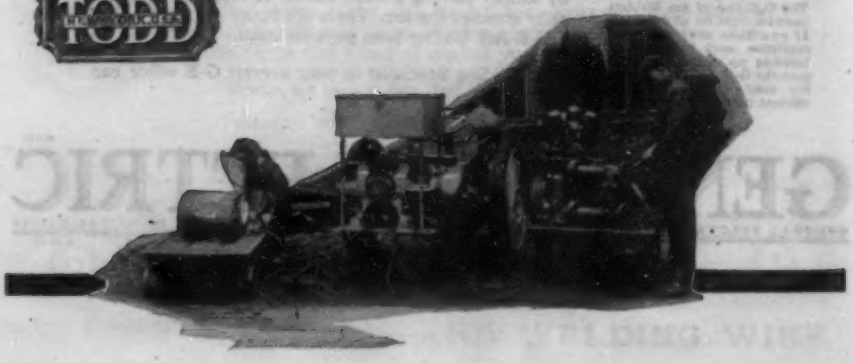

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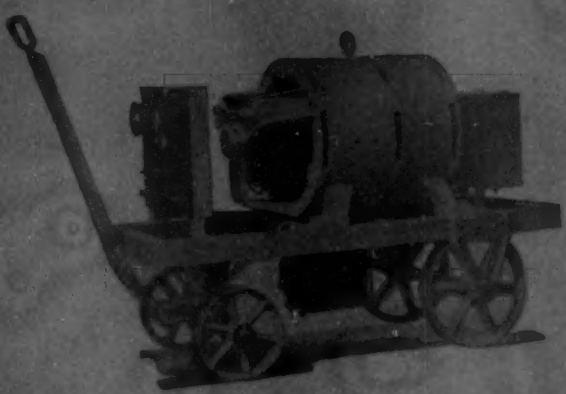

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